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# The hardness–flow stress correlation in metallic materials

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**Abstract.** Hardness is a measure of the resistance of a material to indentation and a wide variety of indentation tests have been devised to measure the hardness of materials. In the case of hardness tests which utilize spherical balls as the indentor, it is also possible to derive flow stress–strain relationships from hardness tests carried out either over a range of loads (static test) or over a range of impact velocities (dynamic test). This paper first describes the experimental procedure for obtaining stress–strain curves from hardness tests. In addition, the paper also analyzes in detail, the indentation test conditions under which the conversion of the hardness–average strain data to flow stress–strain data is simple and straightforward in the sense that the constraint factor which is the correlating parameter for the above conversion is not only independent of strain but also easily computable on the basis of known mechanical property data of the test material.

**Keywords.** Hardness–flow stress; static hardness; dynamic hardness; impact velocity; constraint facto Meyer hardness.

## 1. Introduction

Indentation tests carried out to measure the hardness of materials are usually referred to as hardness tests. Such tests usually involve the indentation of the test material with an indenter at a constant load ($P$) and the subsequent measurement of the dimensions of the indent that is formed on the test material. The hardness ($H$) is then obtained as,

$$H = P/A, \tag{1}$$

where $A$ is the area of the indent formed on the test material. It is more appropriate and scientific to define $A$ as the projected area of the indent rather than surface area, eventhough some of the well-known hardness tests usually define hardness in terms of the surface area of the indent. The hardness values obtained using projected area are usually distinguished from those obtained using surface area of the indent, by specifying the former as the projected area hardness (PAH).

The hardness tests can be classified either on the basis of the indentation test conditions (temperature and strain rate) or on the basis of the depth of indentation, as illustrated in figure 1. The well known conventional hardness tests, called static hardness in figure 1a, are carried out at around room temperature and the strain rate at which the plastic deformation of the test material occurs during indentation, lies in the range $10^{-3}$ to $10^{-1}\,s^{-1}$. In contrast, dynamic hardness, involves strain rates in the range $10^{3}$ to $10^{5}\,s^{-1}$. The hot hardness involves testing the material at temperatures in the range 0·4 to 0·8 $T_m$ ($T_m$ is the melting point of the test material) and at static strain rates ($10^{-3}$ to $10^{-1}\,s^{-1}$). The creep hardness (or impression creep)